Realistic Application and Air Quality Implications of DG and CHP in California

Time Resolved Thermal and Electrical Demand Profiles for Representative California Commercial and Industrial Facilities

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Motivation

- **Distributed generation and combined heat and power (DG/CHP) are expected to be a significant participant in plans for California electric growth portfolio in a reduced GHG emissions (AB32) constrained environment**

- **Fine resolution energy data needed to understand how DG/CHP might actually be deployed most efficiently and effectively while minimizing environmental impacts**
  - **Allows evaluation of DG/CHP deployment within smart grids/microgrids**
  - **Building energy model validation**

Overview of Project

Project Goals

- **Develop on-line database of 15-minute profiles over 12 month period of power, heating, and cooling demand for common facilities (from chosen sectors).**
  - **Includes ambient conditions at or near site (temperature, relative humidity)**
  - **Six sectors identified with high potential of benefit from DG/CHP deployment**
- **Summarize the value of DG/CHP systems in terms of emissions impacts to air shed basin and relative exposure to surrounding public.**
- **Recommend applications that most effectively benefit from DG/CHP installation in terms of overall efficiency and air quality impacts.**

Overview of Project

Unique aspects of this effort

- Resolution of existing data sets is hourly at best. This program will monitor at 15 min interval or better.
- Existing data is of limited duration. This effort will monitor sites for nominally 12 months continuous to ascertain seasonal variations.
- Existing data does not capture distributed generation component as sites. This effort will monitor on site DG/CHP where it exists and assess impacts.

Approach

Project Technical Tasks:

- Sector Identification and Facility Engagement
- Gather Thermal and Electrical Demand Data
- Database Generation
- Comparison of DG/CHP Utilization
- Relative Exposure Analysis

Sector/Facilities Identification

- **Goal: Identify Sectors that would likely benefit greatest or have the greatest impact on energy consumption from both total energy perspective and the potential application of combined cooling and/or heating by utilization of exhaust waste heat.**
- **Input from Databases, Reports, Advisors:**
  - **“Assessment of California CHP Market and Policy Options for Increased Penetration”**
    - **PIER-CEC/EPRI/EEA Report 2005, CEC-500-2005-060-D**
  - **“California CEUS*—California Commercial End Use Survey”**
    - **Itron CEC Report CEC-400-2006-005**
  - **California SGIP Applications/Awards data base**
  - **Input from Technical Advisory Board**

Sector/Facilities Identification

Identified Target Sectors

- Hotels
- Jails/Prisons/Correctional Facilities
  - **Approx $500 M to $1 B in energy costs per year for CDCR facilities only.**
- Colleges/University
- Hospitals/Healthcare
- Commercial Buildings
- Food Services (Warehousing, retail supermarkets)
  - **Supermarkets and food warehousing have 24/7 HVAC load for refrigerator/freezer operation.**

Sector/Facilities Identification

Current Status

- Facilities Approached
  - 96 separate institutions
  - 196 facilities
  - 54 engaged
    - (21)Commercial Office
    - (9) Schools (University/Colleges)
    - (9) Jails/Prison
    - (6) Food (Grocery/Warehouses)
    - (3) Hotels
    - (6) Hospitals/Healthcare (out-patient clinics)

Data Base Generation

SQL Data base: 64 data columns

- Site ID
- Time (date and time)
- Ambient temperature
- Relative Humidity
- Total Electric In
- Total Gas In
- Total HVAC Chilling and Heating
- Total Process Chilling and Heating
- Total Fuel Based on-site Power
- Total Non-fuel based on site power (e.g. solar, wind)
- On Site DG waste heat recovery
  - Hot water
  - Chilling
  - other
- On Site DG Fuel to Electric and overall thermal efficiency

- Calculated Ratios of HVAC and process chilling and heating to total Energy input

- Normalized Energy parameters:
  - Total Electric
  - Total Energy
  - HVAC Chilling
  - HVAC heating
  - Process Chilling
  - Process Heating

  Per sq-ft of building size

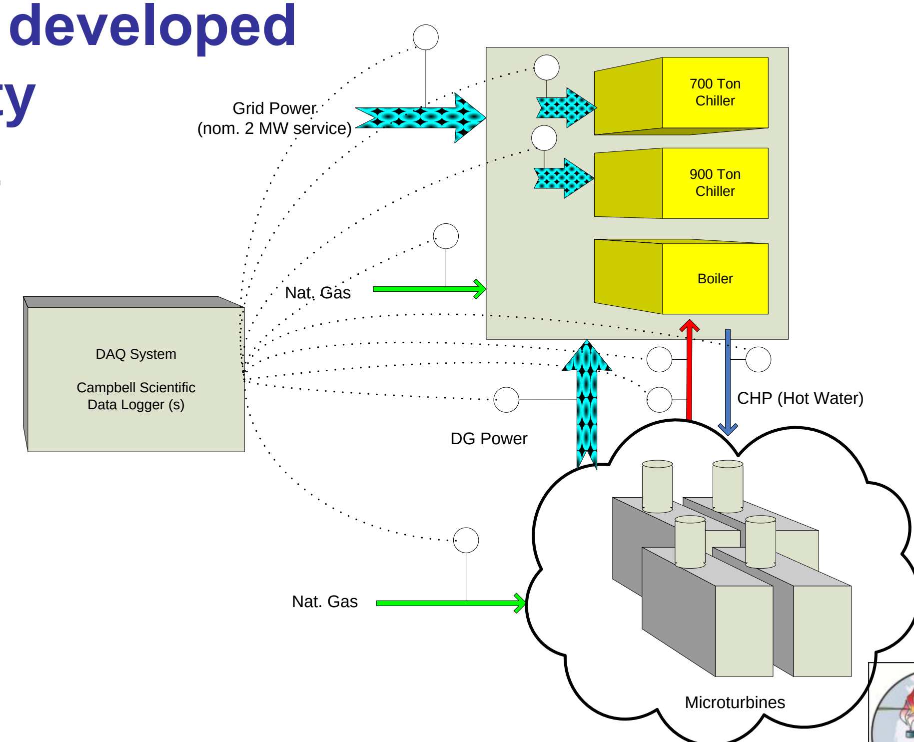
- Sector Specific Normalizations

  Above parameters normalized to
  - # students (colleges/universities)
  - # beds (hospitals, hotels)
  - # occupants (jails/prisons)
  - # occupants (commercial office buildings

Data Base Generation

Current Status

- Completed instrumentation installations for monitoring
- Currently “on-line” with retrieval of data from some hospital sites and college/university sites to further populate.
- A palette of “translators” developed to import data from variety of data sets to consistent data set for SQL
- SQL data base is nearing completion



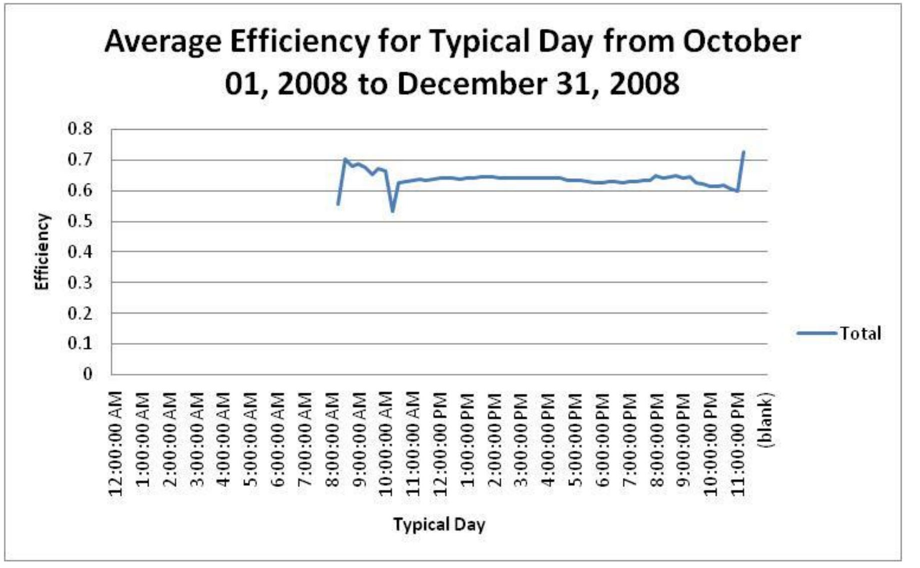
Example Analyses

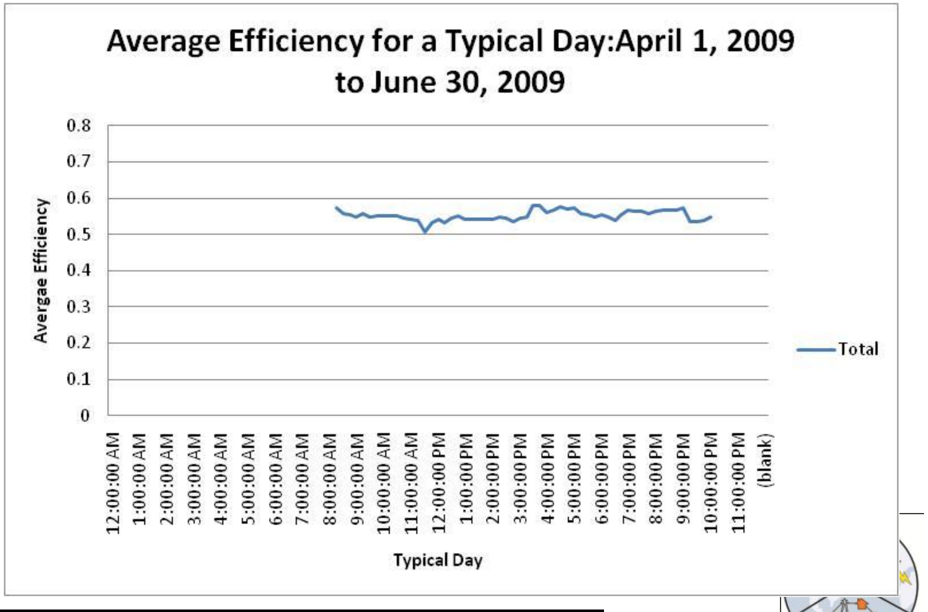
- **DG/CHP Utilization**
  - **Cases with DG/CHP**
- **Facility/Sector Energy Utilization**
  - **“Test” technical fit of DG/CHP Options**
- **Relative Exposure**
  - **Impact of DG/CHP Deployment in Target Markets**
  - **Potential Local population impacts**

DG/CHP Utilization

Microturbine in Commercial Office Building

- 7 MTG total:
  - 3 MTG+ WHR
  - 4MTG + WHR
- Efficiency based upon LHV (920 btu/scf)
- 8 am to 11 pm scheduled operation

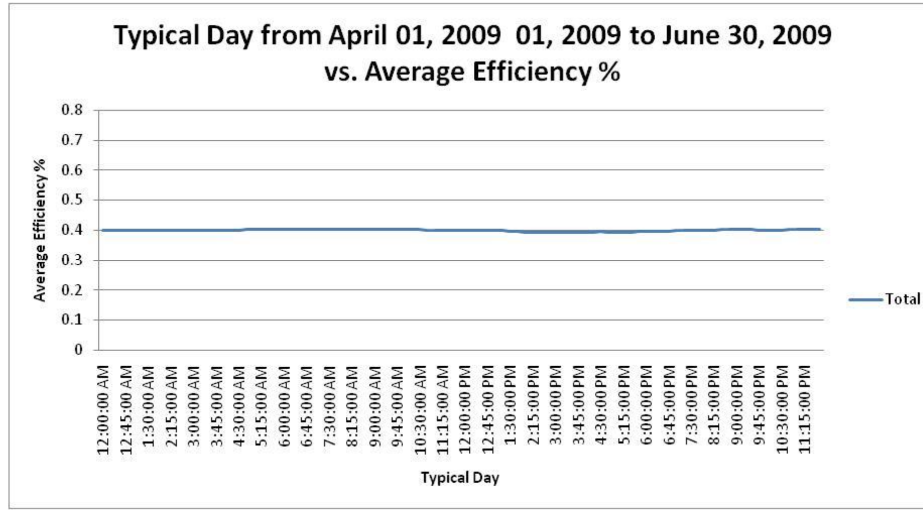


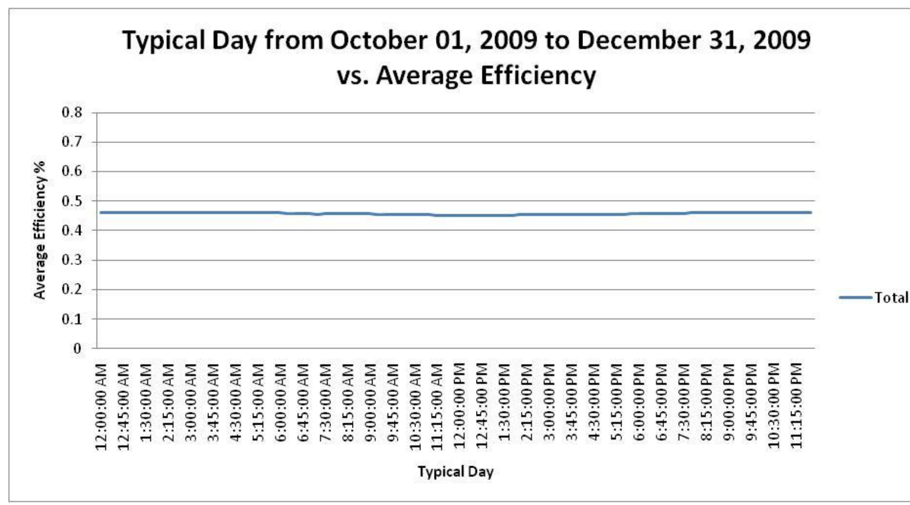


DG/CHP Utilization

Fuel Cell on university campus

- **1 MW total:**
  - **4 x 250 kW**
  - **Waste Heat recovery implemented and tuned during monitoring. Not included in efficiency analysis here**
- **Efficiency based upon LHV (920 btu/scf)**
- **24/7 operation**



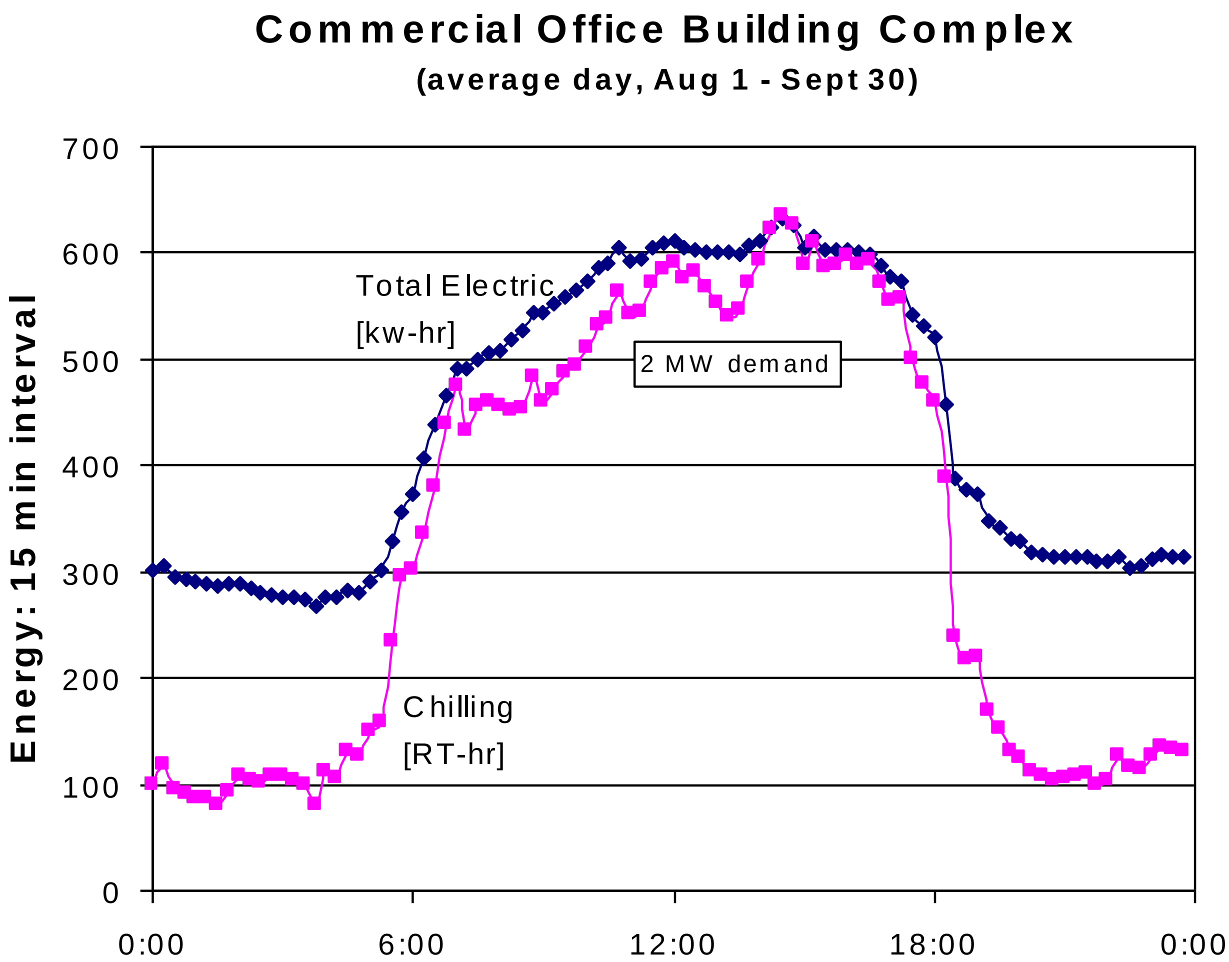


Energy Data

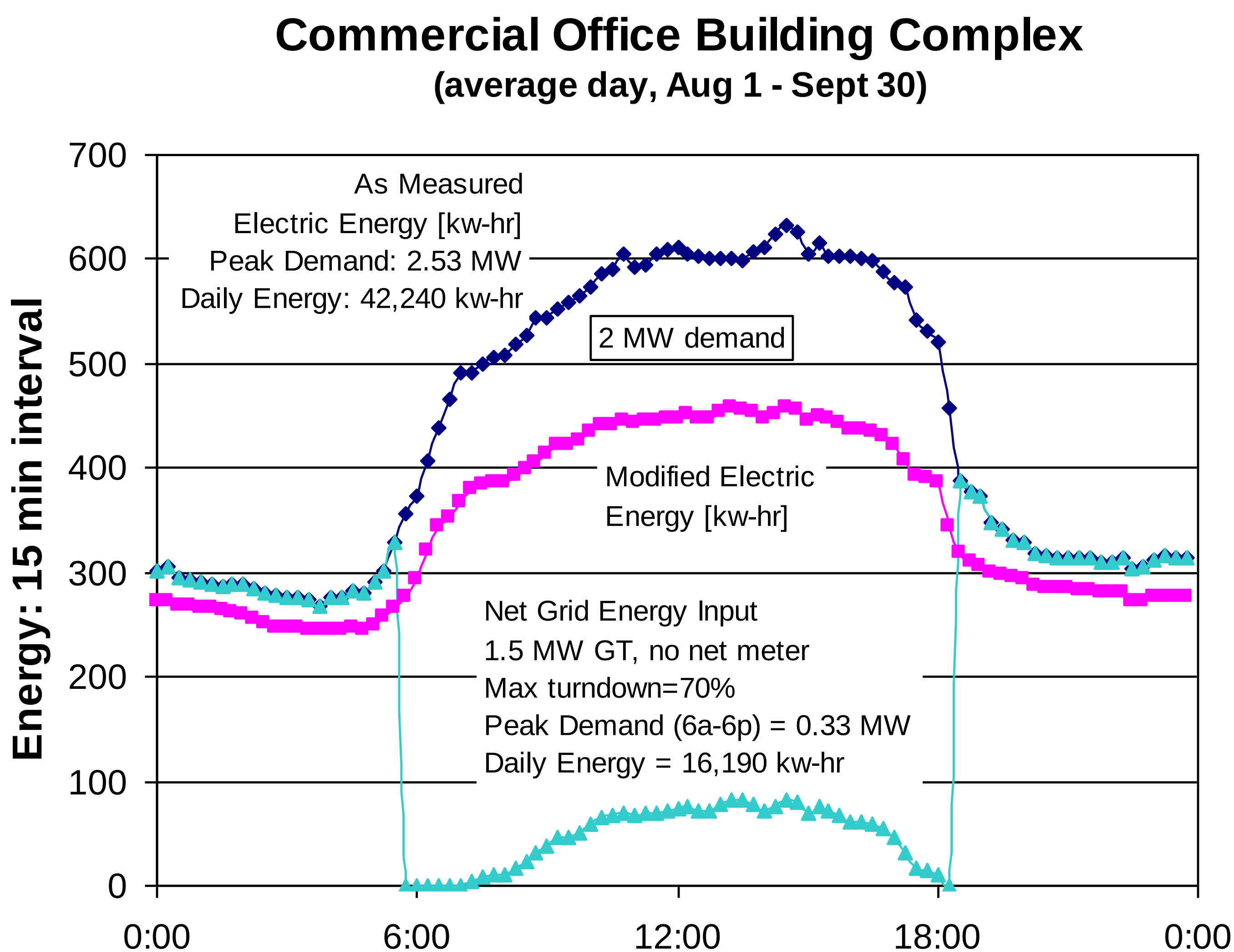
- Following are data from two representative facilities
- Presented are “typical 24 hour day” information based upon several month sampling periods.
  - Averaged values for 15 min periods – 96 points per day
- Presented data include (on 15 minute intervals)
  - Total electric energy
  - HVAC loads
  - Other Process Loads (refrigeration)
- Potential impact of DG / CHP on facility loads.
- Hypothetical DG sized to meet thermal/process loads to obtain maximum efficiency and impact.
  - Maximum utilization of fuel energy to generate both electric power and optimize waste heat recovery

Typical Data - Commercial Office

Multi-Tower Commercial Office Building
- **1.11 million sq-ft**
- **Central Plant**
- **TES**



Typical Data - Commercial Office



Application:

-1.5 MW Turbine. Assume max turndown of 70%

-Double Effect Absorption Chiller

- No Export of electricity to grid

Results:

-Mid-day peak demand reduced 86%

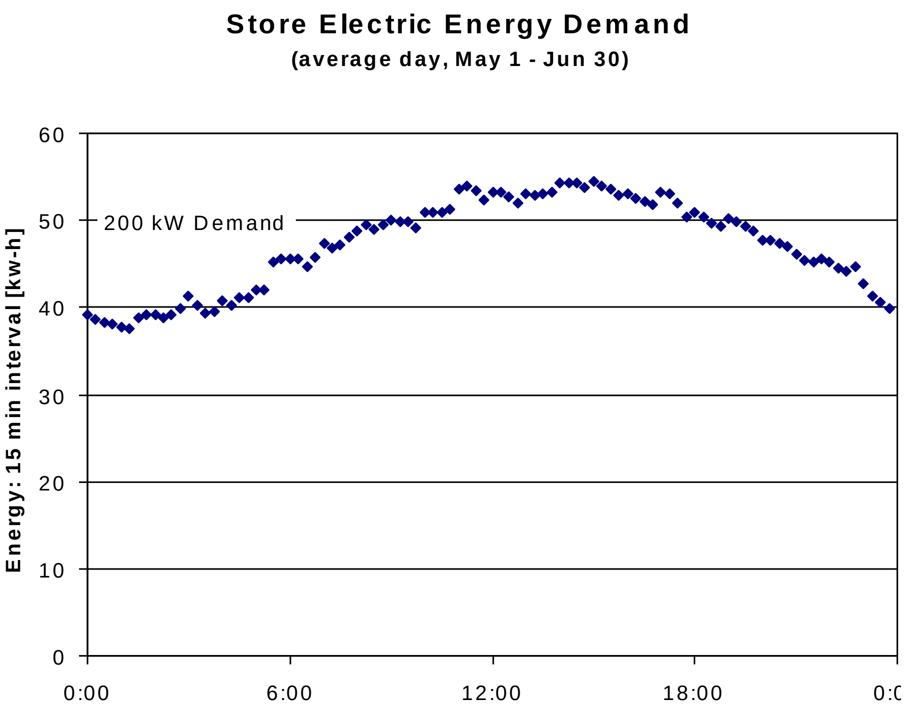
-Daily Energy need reduced 62%

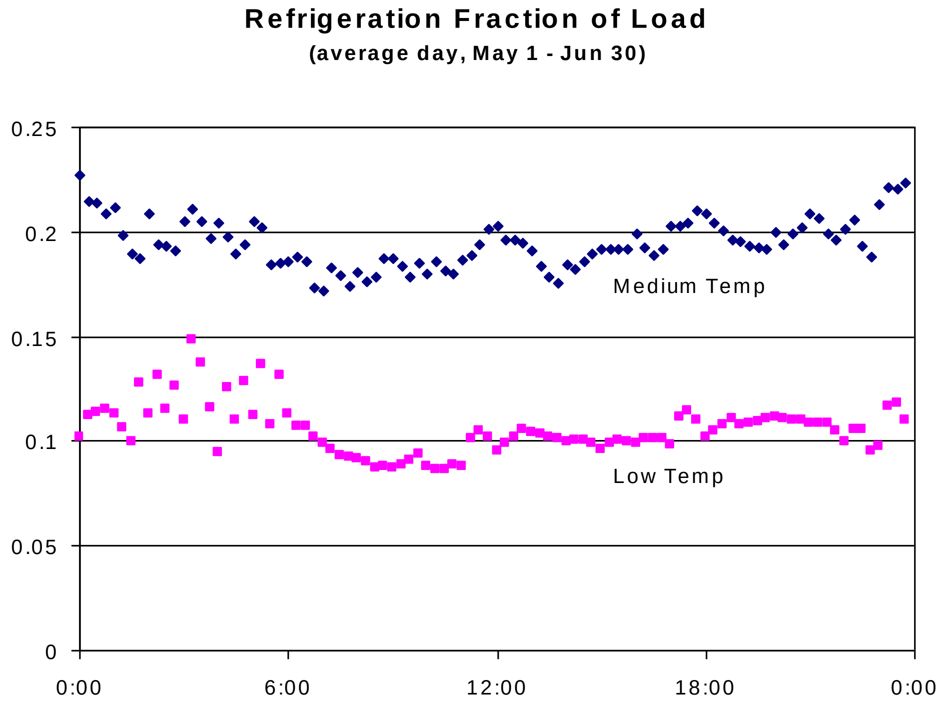
-Vast Majority of chilling load during operation of turbine met by absorption chiller

Typical Data – Grocery Stores

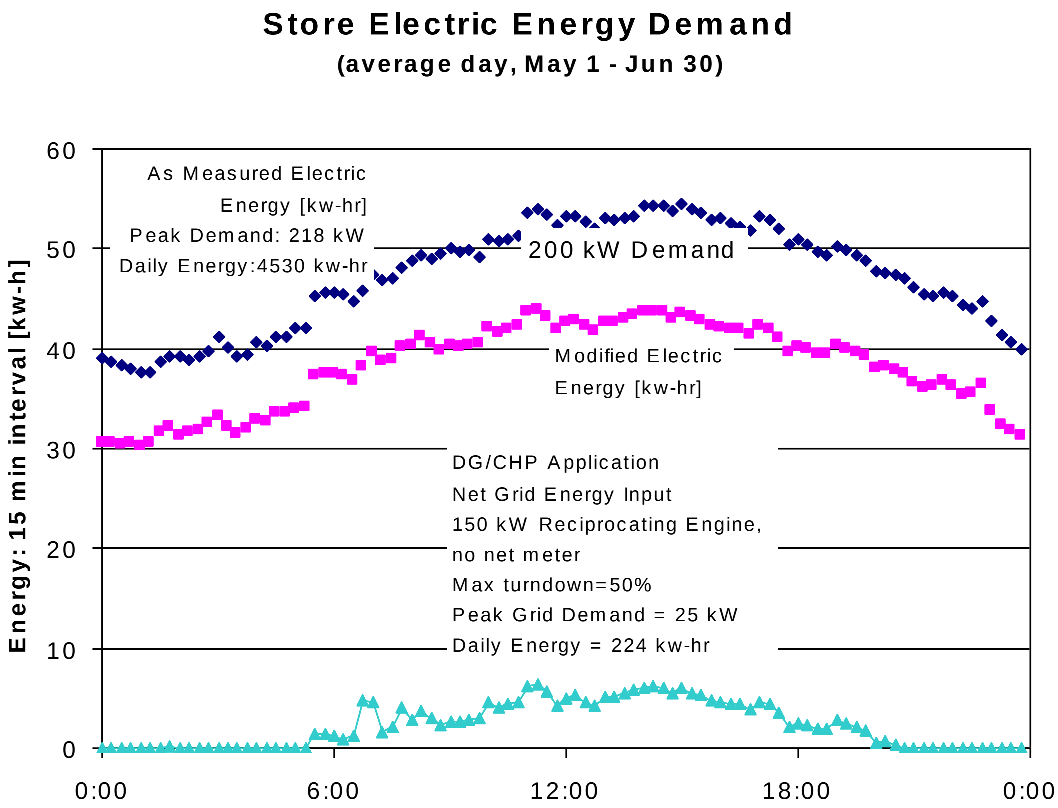
- **Major Chain Grocery Store;**
  - **~28,500 sq-ft retail floor space; ~43,500 sq-ft total space**
- **Less than 10 years old – relatively modern systems**
- **Refrigeration Systems: Freon based compressors with local expansion of coolant in cases/cabinets**
  - **Low temp; < -20 deg F**
    - **frozen foods, ice cream**
  - **Medium temp; approx 25 F but tempered locally for needed temperatures**
    - **Meat, dairy, produce**
    - **New systems are being developed for liquid chiller cooling rather than air cooling (Hill Phoenix).**
    - ***Suitable for absorption chilling with ammonia chiller systems***
  - **Sub-cooling: approx 60 F**
    - **increases efficiency of LT and MT compressors by pre-cooling discharge of compressor prior to expansion at case/cabinets**
    - **Temperature compatible with absorption chilling**

Typical Data – Grocery Stores





Typical Data – Grocery Stores



Application:
- 150 kW Recip Engine for DG/CHP
- Single Effect Absorption Chilling:
  - Subcooling –LiBr
  - Med. Temp -ammonia
- Air Conditioning Load is low

Results:
- Peak demand reduced 88%
- Daily Energy need reduced 95%

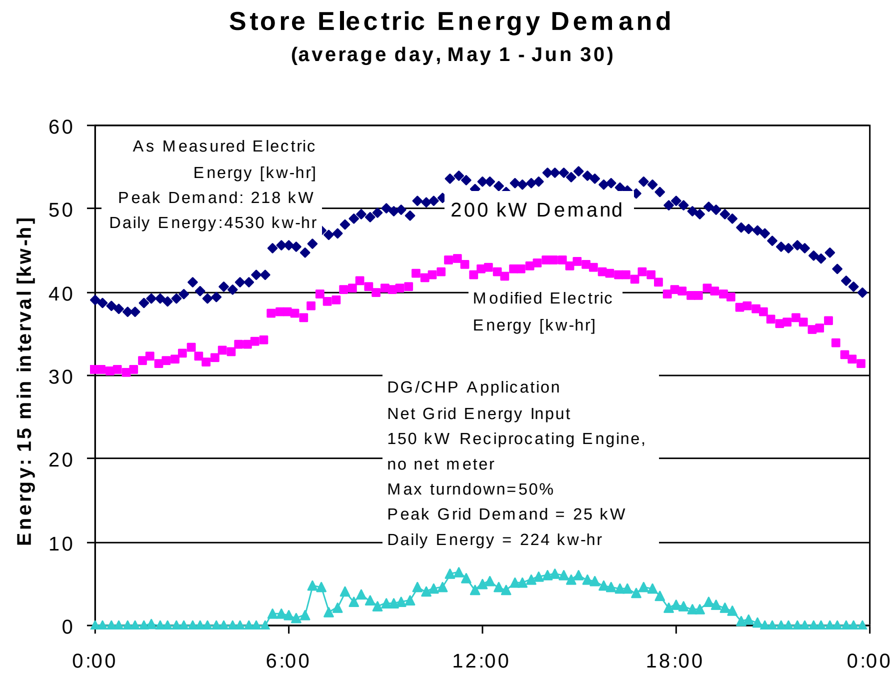
Peak: 218 kW currently; 25 kW w/ DG/CHP
(88% reduction)
Daily: 4530 kW-hr currently; 224 kW-hr with DG/CHP
(95% reduction)

Typical Data -- Grocery Store

Energy $ Savings

- **Summer: SCE TOU-GS-3 Opt B (5/08):**

Demand Reduction [kw]			
	off	mid	peak
kw	160	180	190
$/kw	$9.86	$15.47	$26.22
Energy Reduction			
kw-hr	1530	1620	1150
$/kw-hr	$0.041	$0.079	$0.108



- <u>**Total Electric Grid Savings (month):**</u>
- **$5700 energy + $9650 demand[1]**
- **Cost to operate engine[2]: 4300 kw-hr → $295 (day) x 31 day = $9145**
- **Est. Net Savings[3,4]: <u>$6220</u> (60% red.)**

1: week days + weekend (off-peak)

2: (η=25%, $5.00 MMbtu NG):

3: 21 weekdays + 10 weekends (off peak)

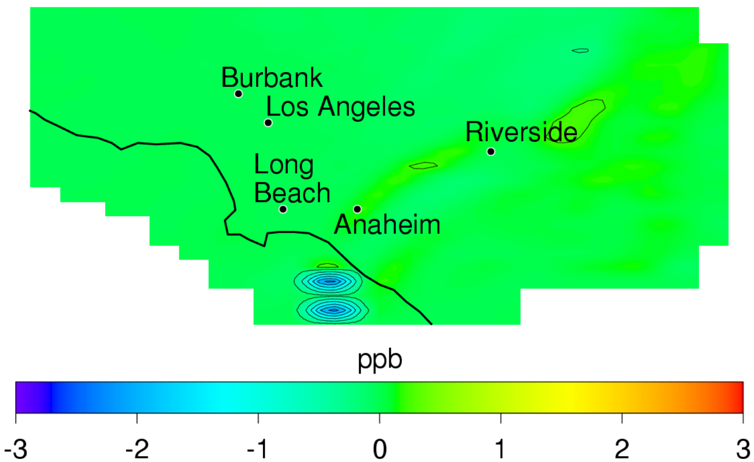
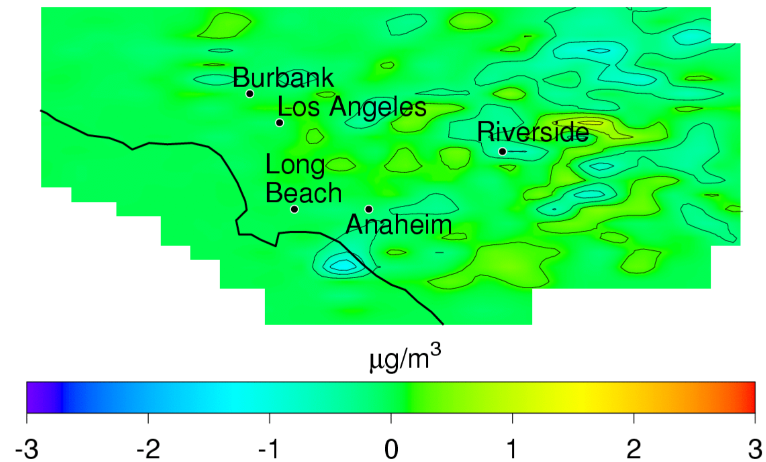
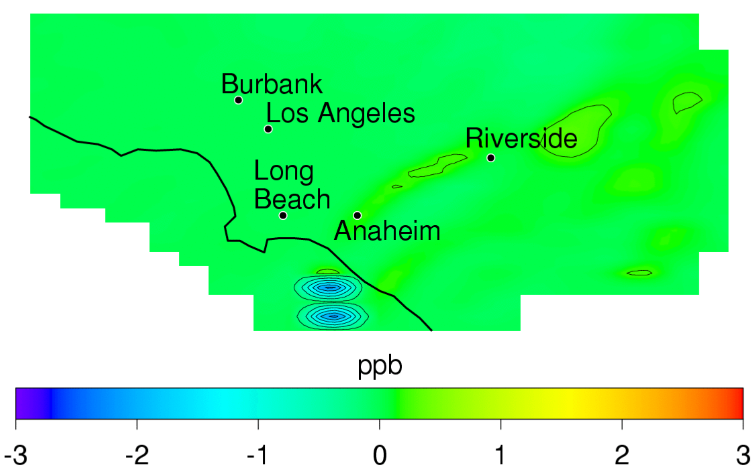
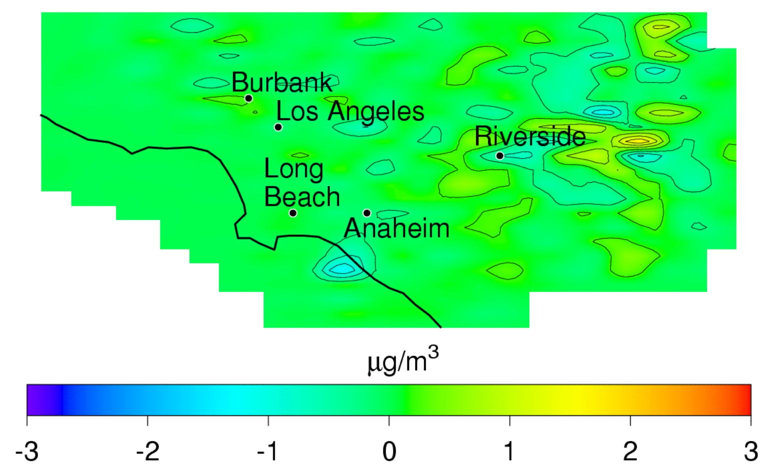
4: $15,361 electric - $9145 NG

Relative Exposure: Air Basin Impacts

- Analysis using APEP's STREET Model
- Assess Impact of DG Deployment:
  - Grocery Stores
- DG to provide
  - Electric power
  - Sub-cooling and medium temp cooling provided by thermally activated cooling (absorption cooling, LI-Br and ammonia)
- Additional cooling needs from grid as necessary
- Emission rates consistent with CARB Certified Levels

- Grocery Store Analysis: offset in load sufficient to remove one powerplant in SoCAB;
  - Huntington Beach: 888 MW
  - Analysis removes this load

Relative Exposure: Air Basin Impacts

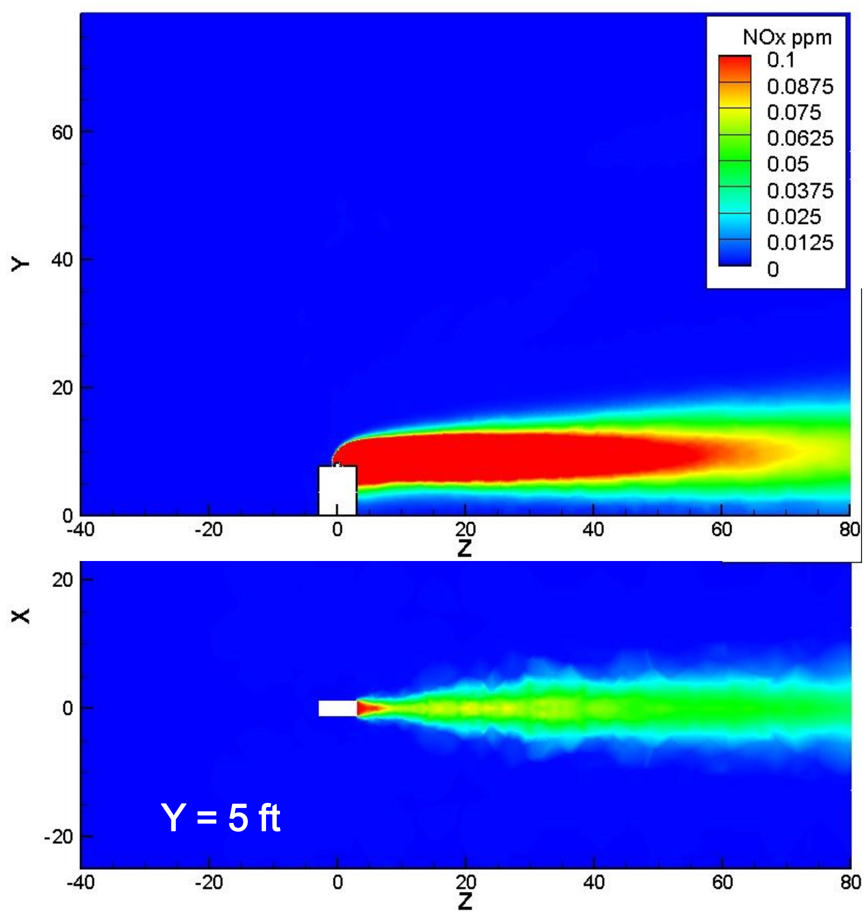
	8 hour Ozone	8 hour PM2.5
MTG		
MCFC		

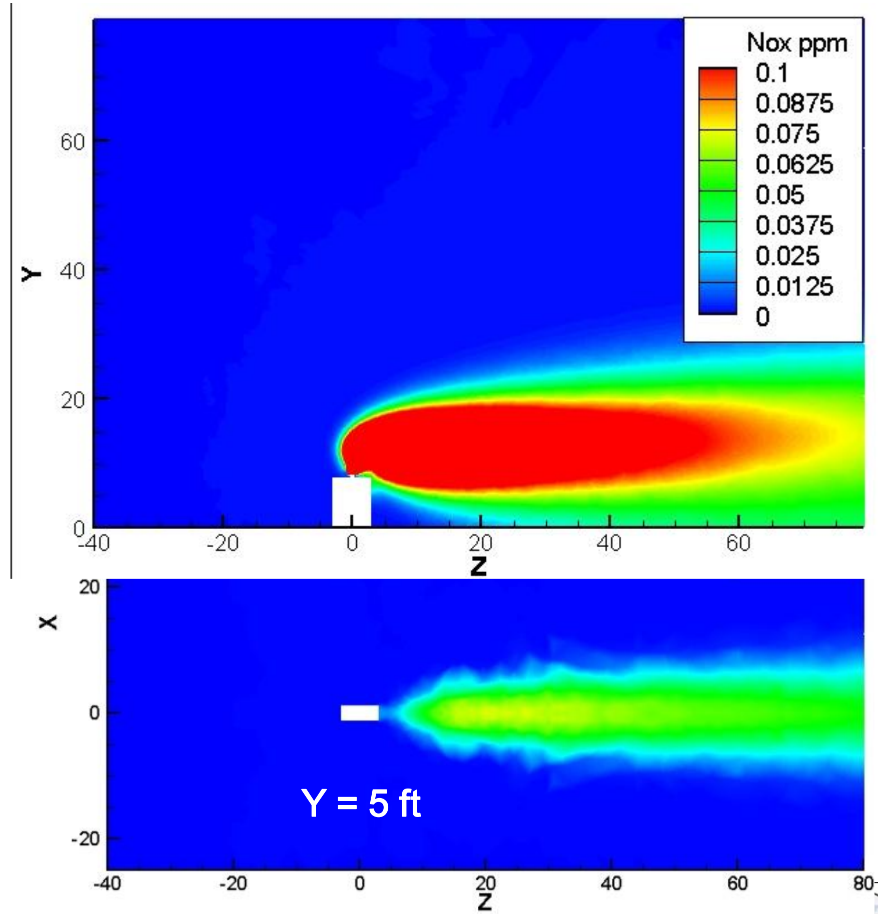
Relative Exposure: Local Impact Analysis

- Need to assess field of influence of DG exhaust
  - "how near is near field"?
- Plume analysis used to establish "near field"
  - 65 kW microturbine
  - Effect of cross wind, stack height, exhaust direction, surrounding buildings
  - NO_2 concentration set at 10 ppmv in stack exhaust
    - Concentration variation calculated to assess dispersion.
  - Concentrations calculated at: ground level, 5 ft, 25 ft
- Indicative, not exhaustive
  - Representative exhaust density
  - Exhaust cooling
  - "worst case" with CHP reduced exhaust temp.
  - No atmospheric turbulence
  - No ground radiation effects
  - No building interaction effects

Plume Dispersion: Open Field

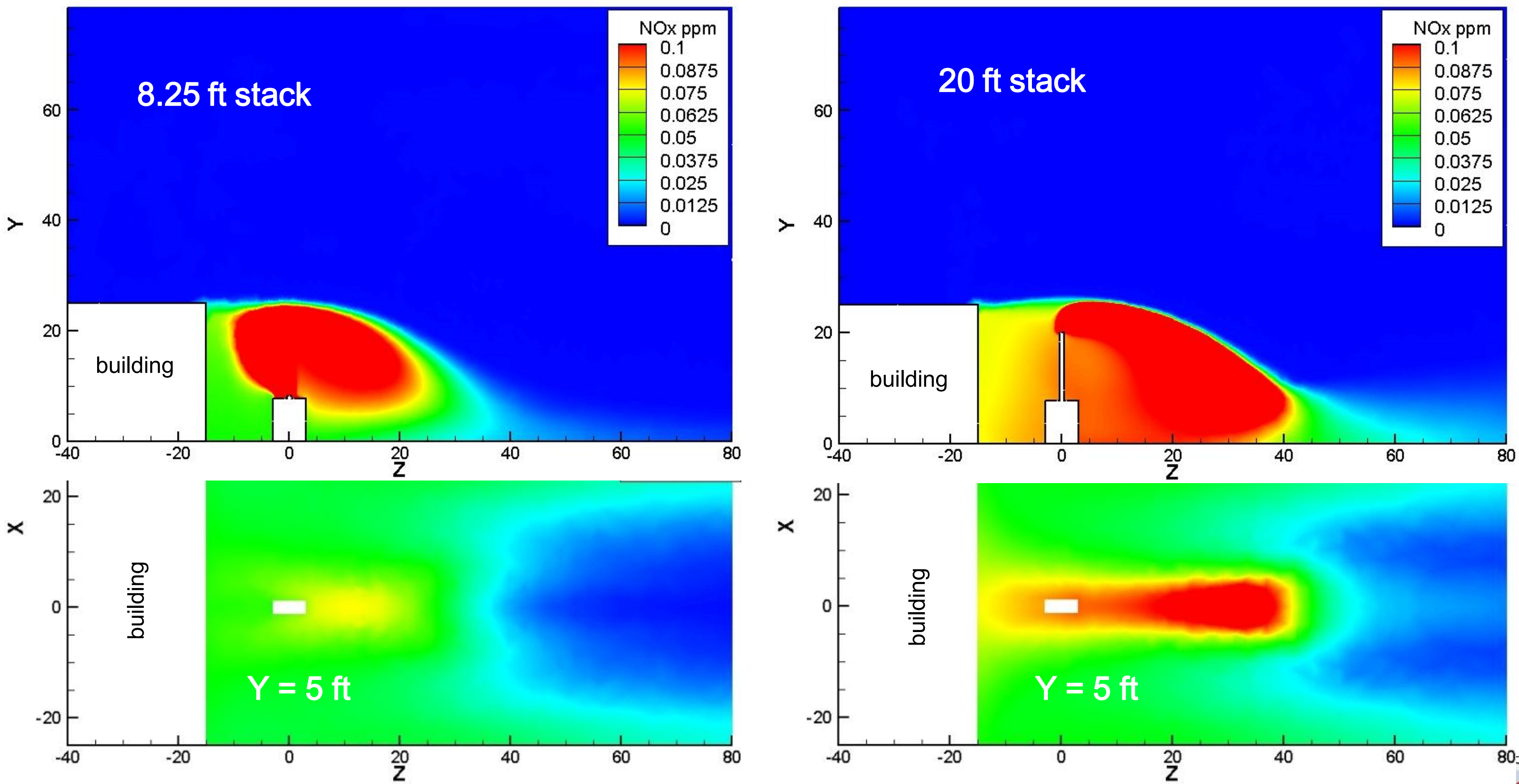
- 15 mph cross wind
- 5 mph cross wind



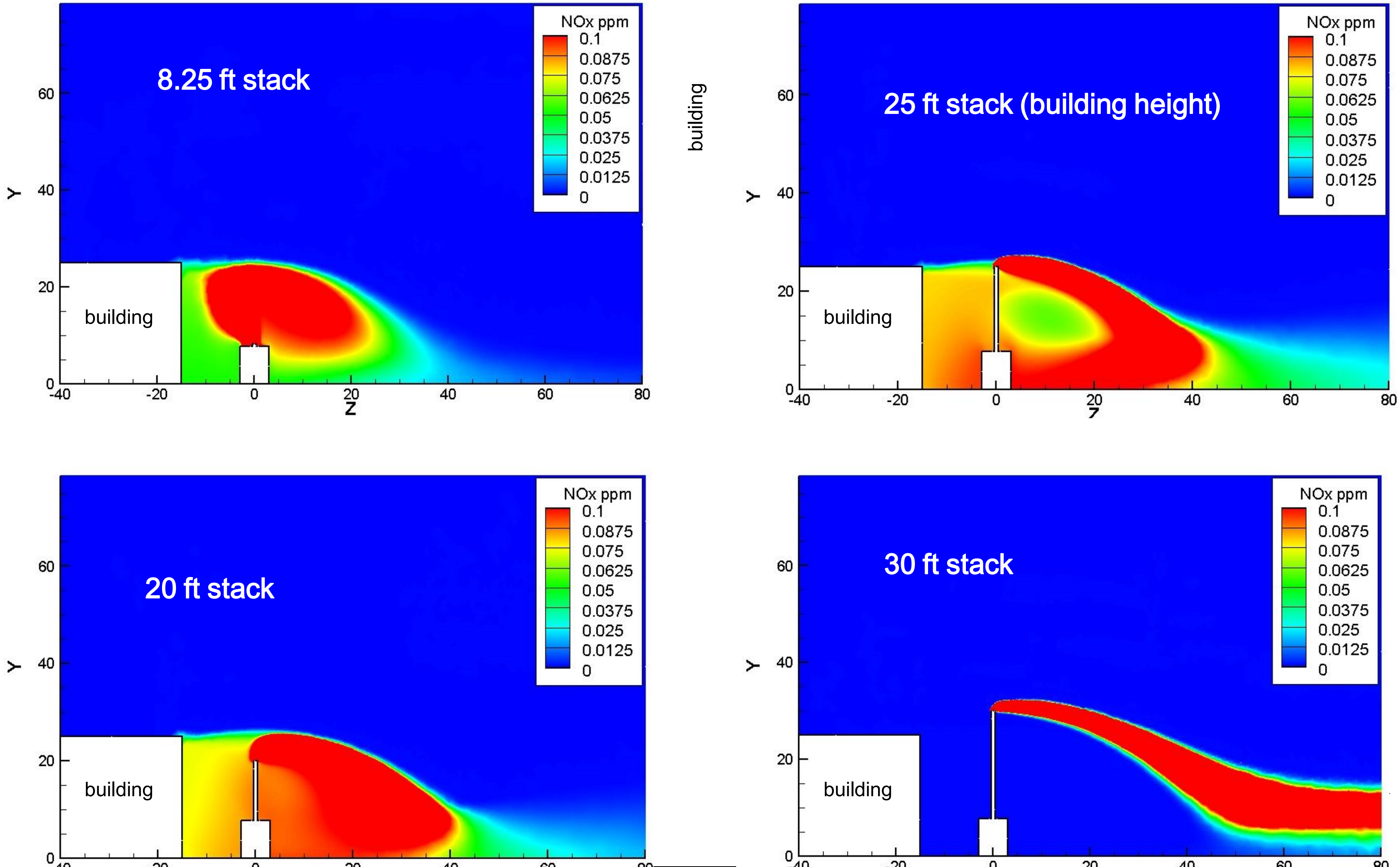


Note: All dimensions in “feet”

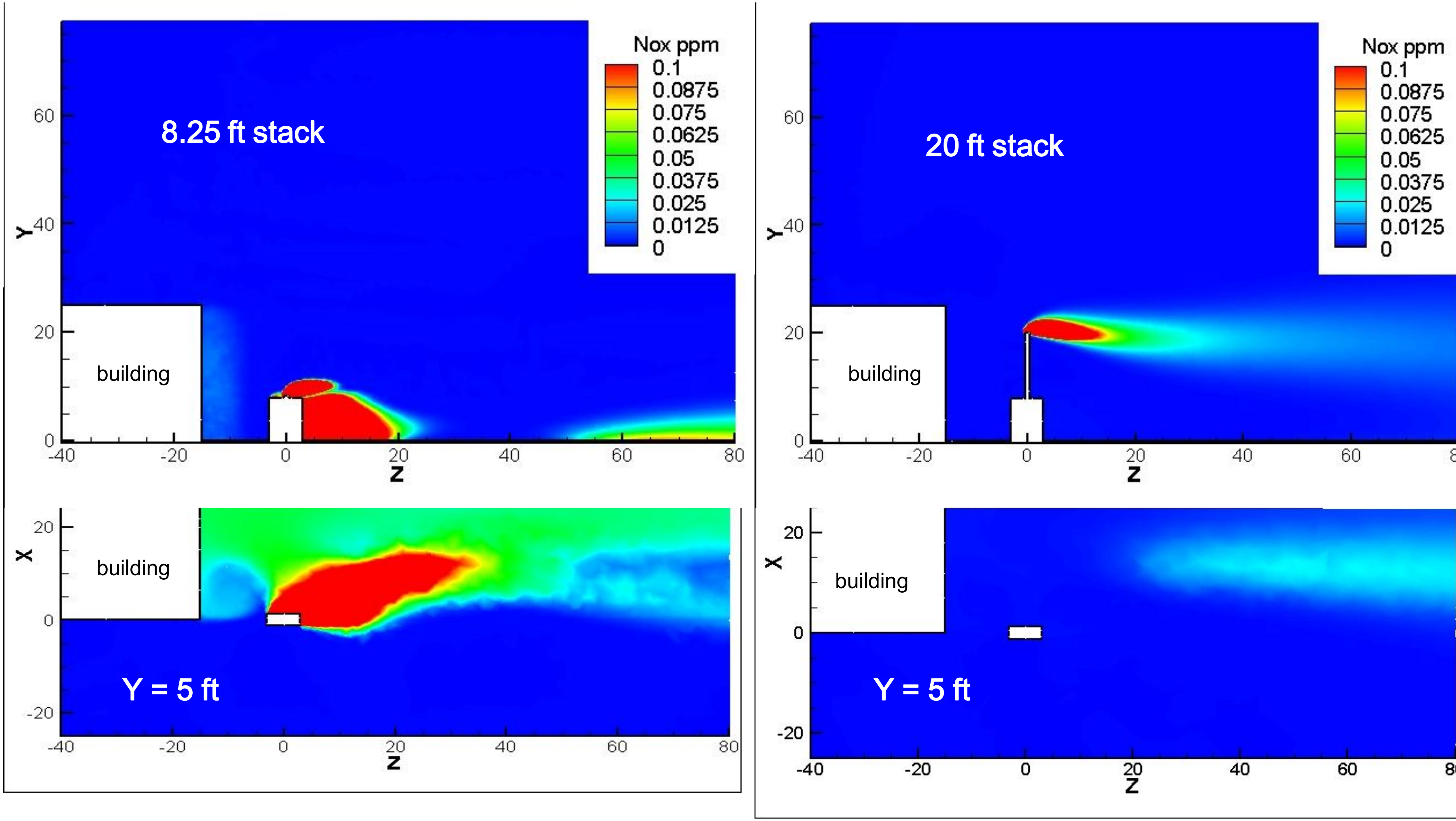
Plume Dispersion: Full Building



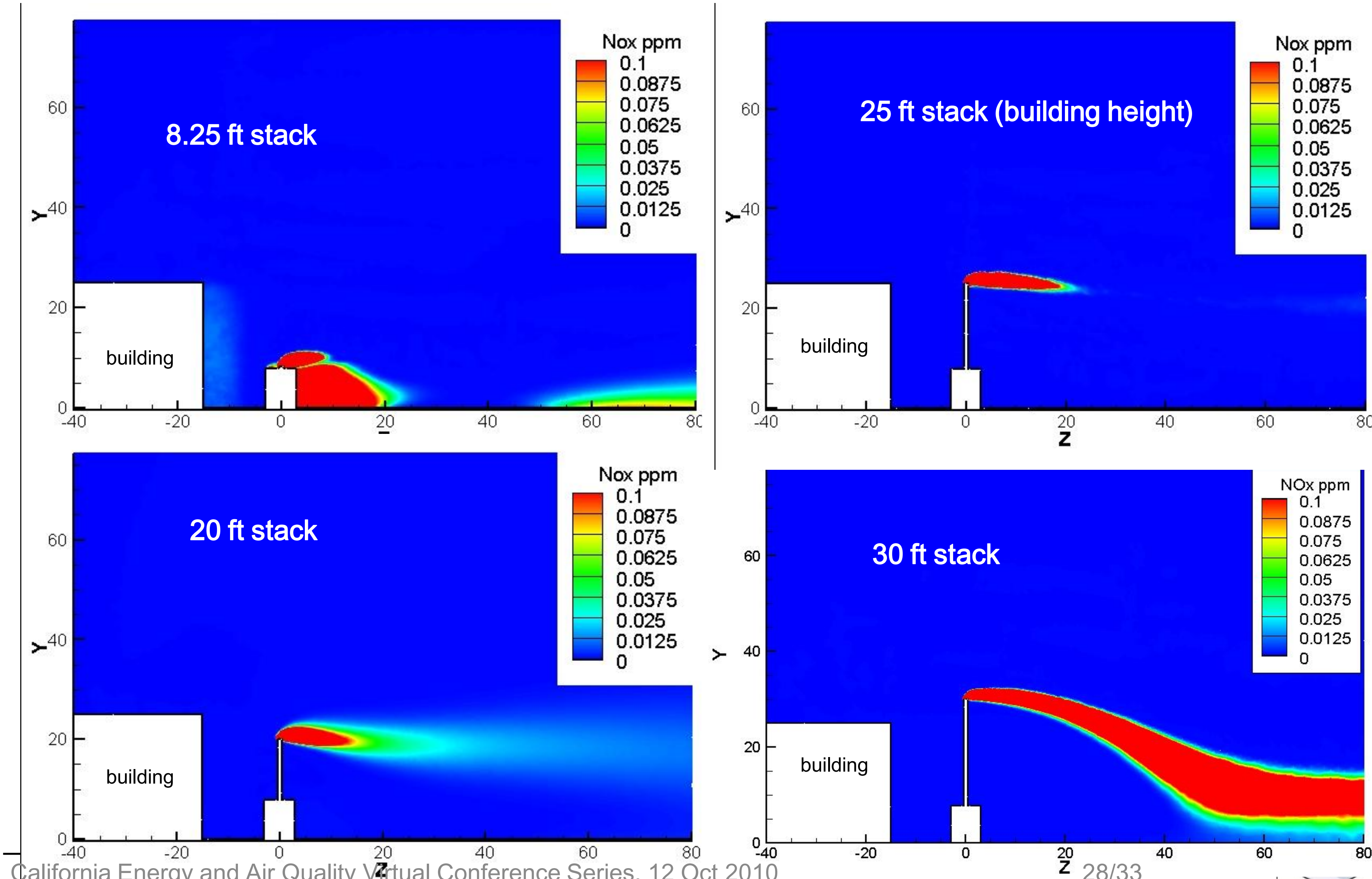
Plume Dispersion: Full Building



Plume Dispersion: Half Building



Plume Dispersion: Half Building



Plume Dispersion: Observations

- Field of influence of DG exhaust
  - Majority of effects occur within 100 ft
  - Consider Near field within 300 ft (100 meters)
- Concentration Dispersion:
  - Concentration quickly diluted 2 orders of magnitude
  - Concentration on the order of ambient air quality standard
    - Inherently not exceeding limits but can contribute to excedance if additive with background levels
- Building and upstream obstructions
  - Consideration of stack height on near field

Relative Exposure

- Utilize GIS data base to identify facilities in sectors of interest.
- Use GIS to assess permanent resident population within region of influence as assessed with plume modeling
  - e.g. within 100 meters
- Determine relative impact of DG distribution on population based upon number of residents impacted
- Currently underway
- Issues to be resolved/considered
  - Transitory population
    - E.g. hotel residents, hospital visitors/patients college students. All not living within area of influence but pass through.

Project Take-Aways

- Sectors identified are generally appropriate candidates for DG/CHP
  - Reluctance to participate limits some information
- Significant Impact to grid energy, efficiency, and cost savings are possible
- Application of small DG in “real world” not well demonstrated (limited sites for program)
  - Efficiencies
    - Waste heat recovery problematic
  - Availability
    - Maintenance; vested interest in equipment
- Application of DG on SoCAB for one sector evaluated has small but positive impact
- Plume effect of DG is limited to region within 100 meters

Future Research

- **Plume Modeling/Local impacts**
  - **Health impacts**
- **Medium temp (~20 F) thermally activated refrigeration**
  - **major load in food/grocery handling and warehousing**
- **Building Energy Model validation**
  - **A number of organization have expressed interest in using measured data for this**
- **Engagement of sites with DG/CHP**
  - **Not in target sectors or not currently using**
  - **Critical to have follow up with installed DG/CHP sites to generate objective data on actual performance**
  - **Impact of performance based SGIP (SB412)**
- **Impacts of Policy Changes**
  - **e.g., AB1613 Feed-in-Tariff→does this change target markets and potential impacts?**

Thank You

California Energy Commission

- **Marla Mueller**
- **Nicole Davis**

Advisory Panel

Advisory Board Contact Point	Organization
Matt Miyasato	SCAQMD
Marty Kay	SCAQMD
Howard Lange	SCAQMD
Mike Waugh	CARB
Dave Mehl	CARB
David Berokoff	Sempra Energy Utilities
Rudy Perez	SCE
Robert Levine	SCE
Dan Heinfeld	LPA
Malcolm Lewis	CTG
Jim Meacham	CTG
Steve Gillette	Capstone Turbine Corporation
Jeff Cox	Fuel Cell Energy
Jim Watts, Andy Freeman	Ingersoll Rand
Chris Lyons	Solar Turbines
Mark Hughes	Solar Turbines
Eric Wong	Cummins Power Generation
John Scallone	California Power Partners
Joe Silva	California Power Partners
Shiva Subramanya	Energy & Power Solutions
Chris Marnay	LBNL
Keith Davidson	DE Solutions
Dr. Akula Venkatram	UCR
Jon Bonk-Vasko	Energy Center (SDREO)
John Sugar	CEC
Simon Minett	Delta Energy & Environment